Design tool for offshore wind farm cluster planning

Hasager, Charlotte Bay; Giebel, Gregor; Hansen, Kurt Schaldemose; Madsen, Peter Hauge; Schepers, Gerard; Cantero, Elena ; Waldl, Igor; Anaya-Lara, Olimpo

Publication date:
2015

Document Version
Peer reviewed version

Citation (APA):
Hasager, C. B. (Author), Giebel, G. (Author), Hansen, K. S. (Author), Madsen, P. H. (Author), Schepers, G. (Author), Cantero, E. (Author), Waldl, I. (Author), & Anaya-Lara, O. (Author). (2015). Design tool for offshore wind farm cluster planning. Sound/Visual production (digital), European Wind Energy Association (EWEA).

Design tool for offshore wind farm cluster planning

Charlotte Hasager (1) Gregor Giebel (1) Kurt S. Hansen (1) Peter Hauge Madsen (1) Gerard Schepers (2) Elena Cantero (3) Igor Waldl (4) Olimpo Anaya-Lara (5)
(1) DTU Roskilde Denmark (2) ECN Petten The Netherlands (3) CENER Pamplona Spain (4) Overspeed Oldenburg Germany (5) University of Strathclyde Glasgow United Kingdom

DTU Wind Energy

EERA DTOC
THE EUROPEAN ENERGY RESEARCH ALLIANCE
DESIGN TOOLS FOR OFFSHORE WIND FARM CLUSTER

Support by

Our proceedings paper

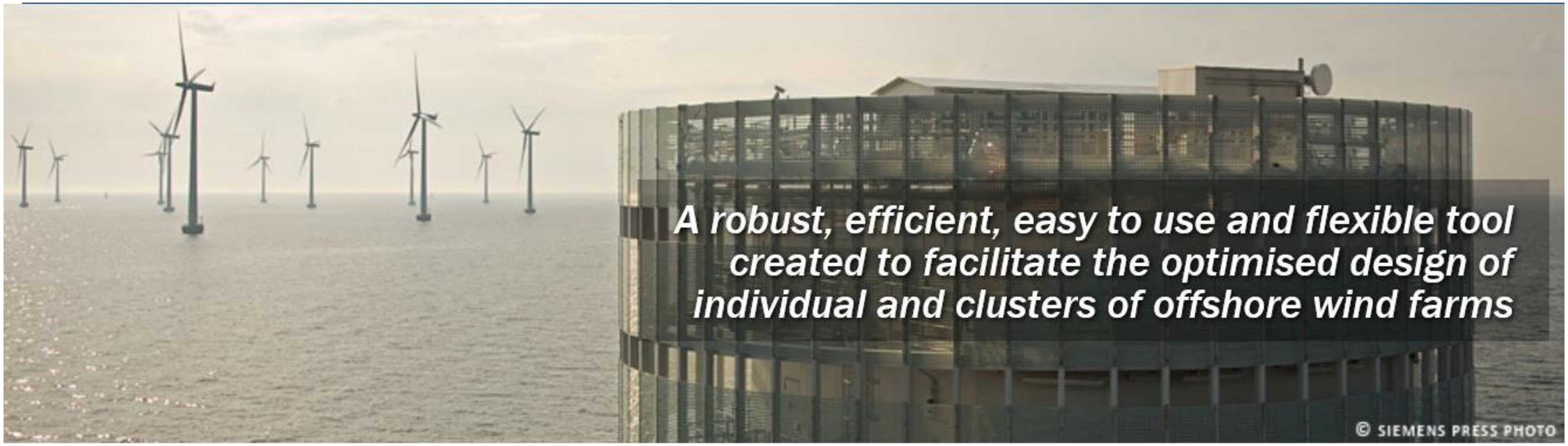
Design tool for offshore wind farm cluster planning

Charlotte Bay Hasager, Peter Hauge Madsen, Gregor Giebel, Pierre-Elouan Réthoré, Kurt S. Hansen, Jake Badger, Alfredo Peña, Patrick Volker, Merete Badger, Ioanna Karagali, Nicolaos Cutulusis, Petr Maule (1), Gerard Schepers, Edwin, J. Wiggelinkhuizen (2), Elena Cantero (3), Igor Waldl (4), Olimpo Anaya-Lara, A.B. Attya (5), Harald Svendsen (6), Ana Palomares (7), Jose Palma, Vitor Costa Gomes (8), Julia Gottschall, Gerrit Wolken-Möhlmann, Ilona Bastigkeit (9), Hauke Beck, Juan Jose Trujillo (10), Rebecca Barthelmie (11), Giorgos Sieros, Takis Chaviaropoulos (12), Pauline Vincent, Romain Husson (13), John Prospathopoulos (14)

(1) DTU Wind Energy, Roskilde, Denmark, cbha@dtu.dk, phone +45 21327328, (2) ECN, Petten, The Netherlands, (3) CENER, Sarriguren,Spain, (4) Overspeed, Oldenburg, Germany, (5) University of Strathclyde, Glasgow, UK (6) SINTEF Energy Research, Trondheim, Norway, (7) CIEMAT, Madrid, Spain, (8) University of Porto, Porto, Portugal, (9) IWES Fraunhofer, Bremerhaven, Germany, (10) FORWIND, University of Oldenburg, Oldenburg, Germany, (11) University of Cornell, Ithaca, NY, USA, (12) CRES, Athens, Greece, (13) CLS, Plouzane, France, (14) NTUA, Athens, Greece

Project partners

EERA DTOC project vision



Danish article

Streamlining project planning of offshore wind farms

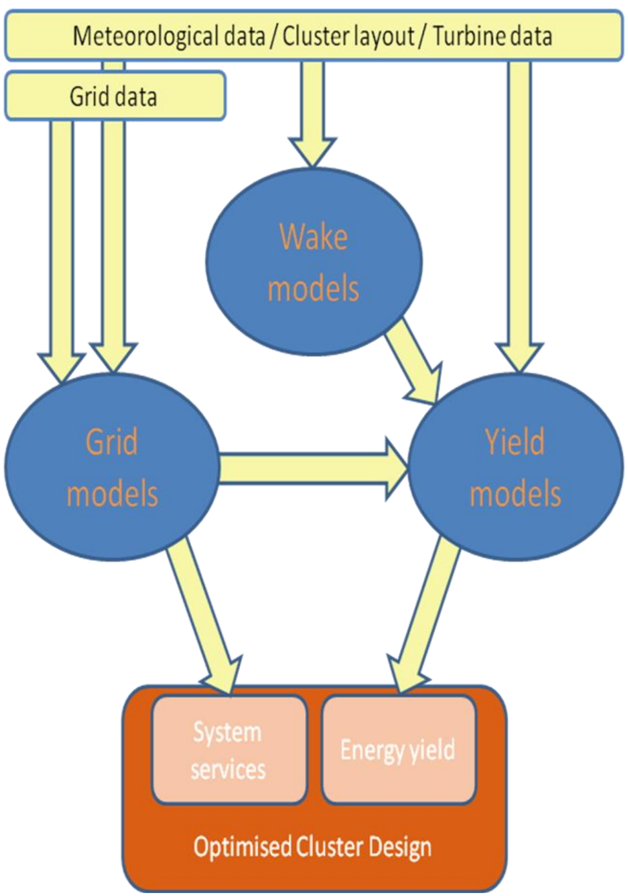
Even though offshore wind farms are incredibly expensive—and a great deal of time is devoted to planning them—communication between project developers leaves a lot to be desired. Simply put: one expert often has little idea what another is doing, and this costs a lot of time and money. However, this situation may soon be history thanks to a new tool developed by DTU Wind Energy in Roskilde.

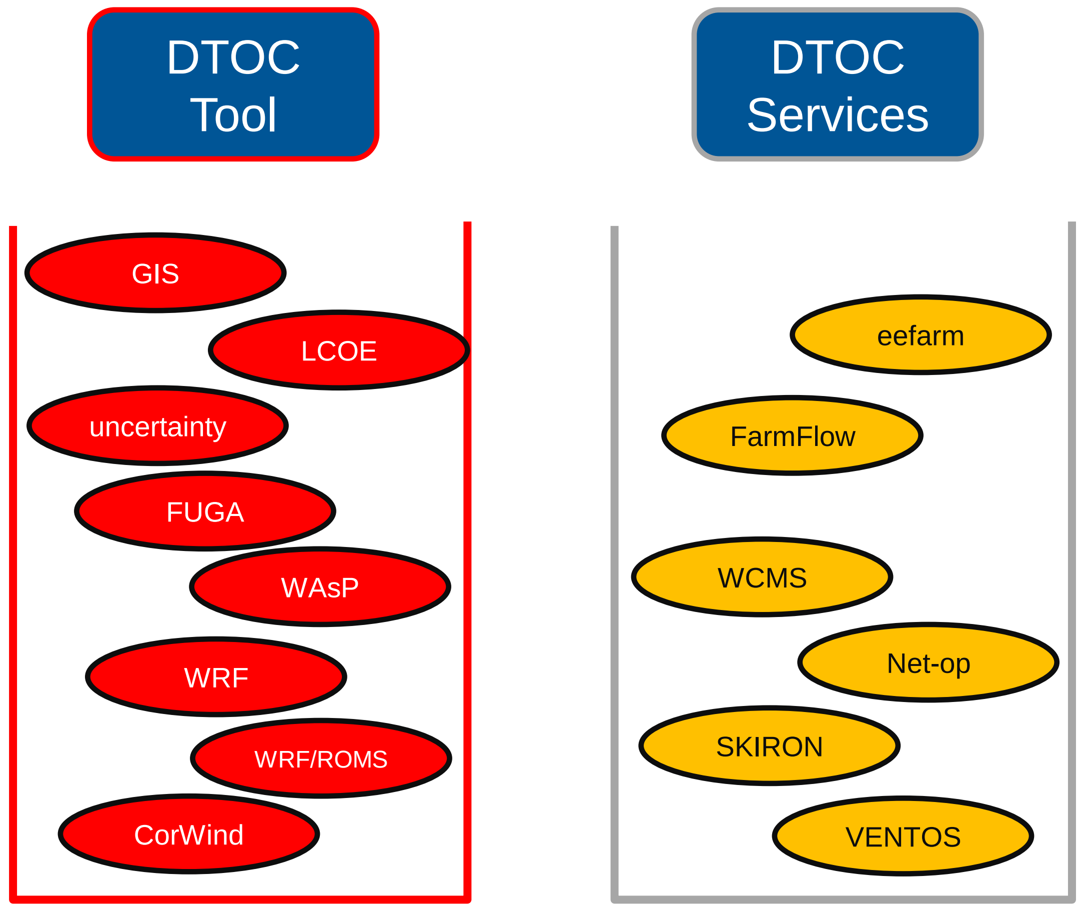
http://www.dtu.dk/english/News/2015/04/Offshore-wind-farms-to-be-developed-with-a-single-model?id=c3435bfd-ef12-42cf-8f39-fd5fa8e948c8

EERA DTOC main components

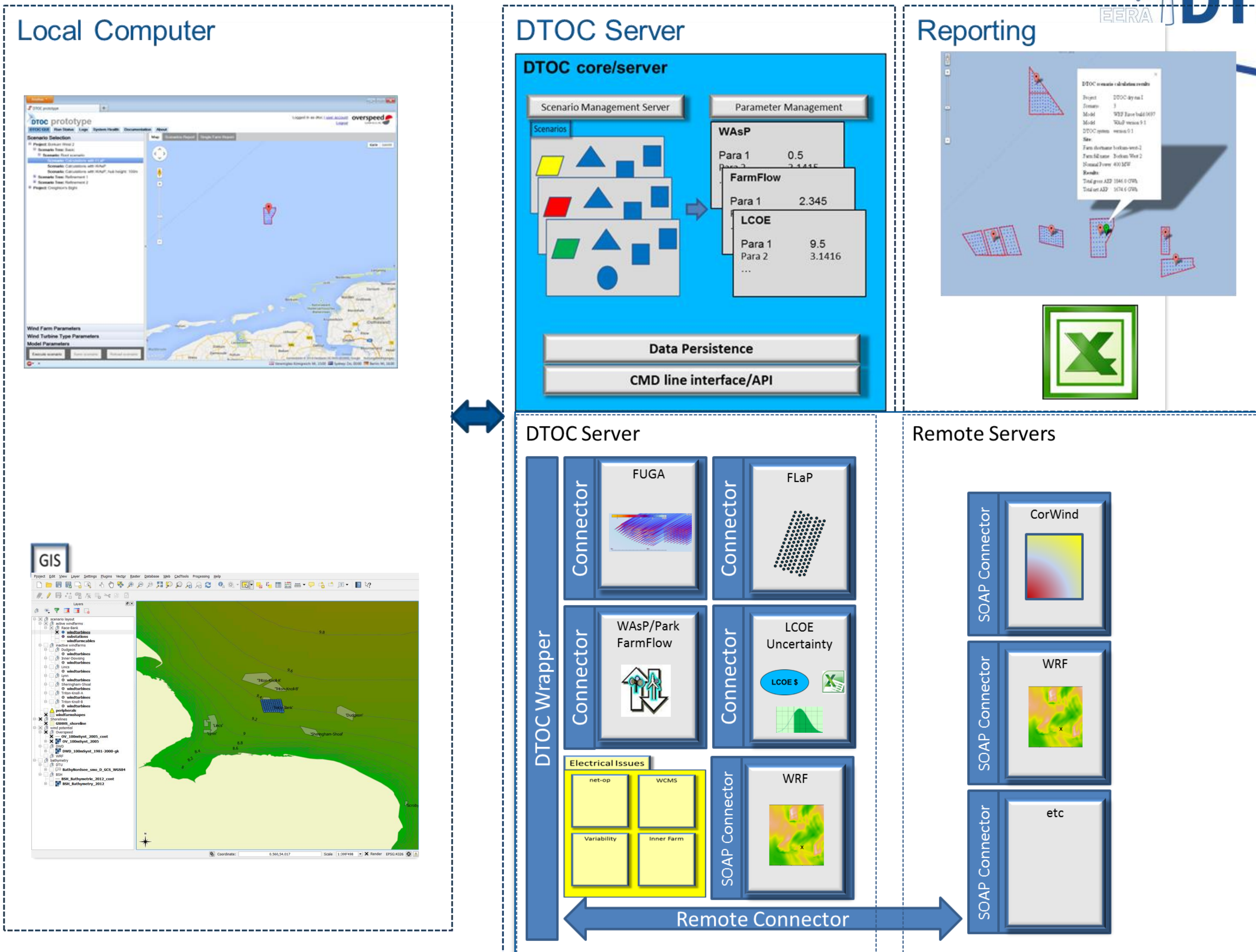
- Use and bring together existing models from the partners
- Develop open interfaces between them
- Implement a shell to integrate
- Fine-tune the wake models using dedicated measurements
- Validate final tool

Concept and implementation

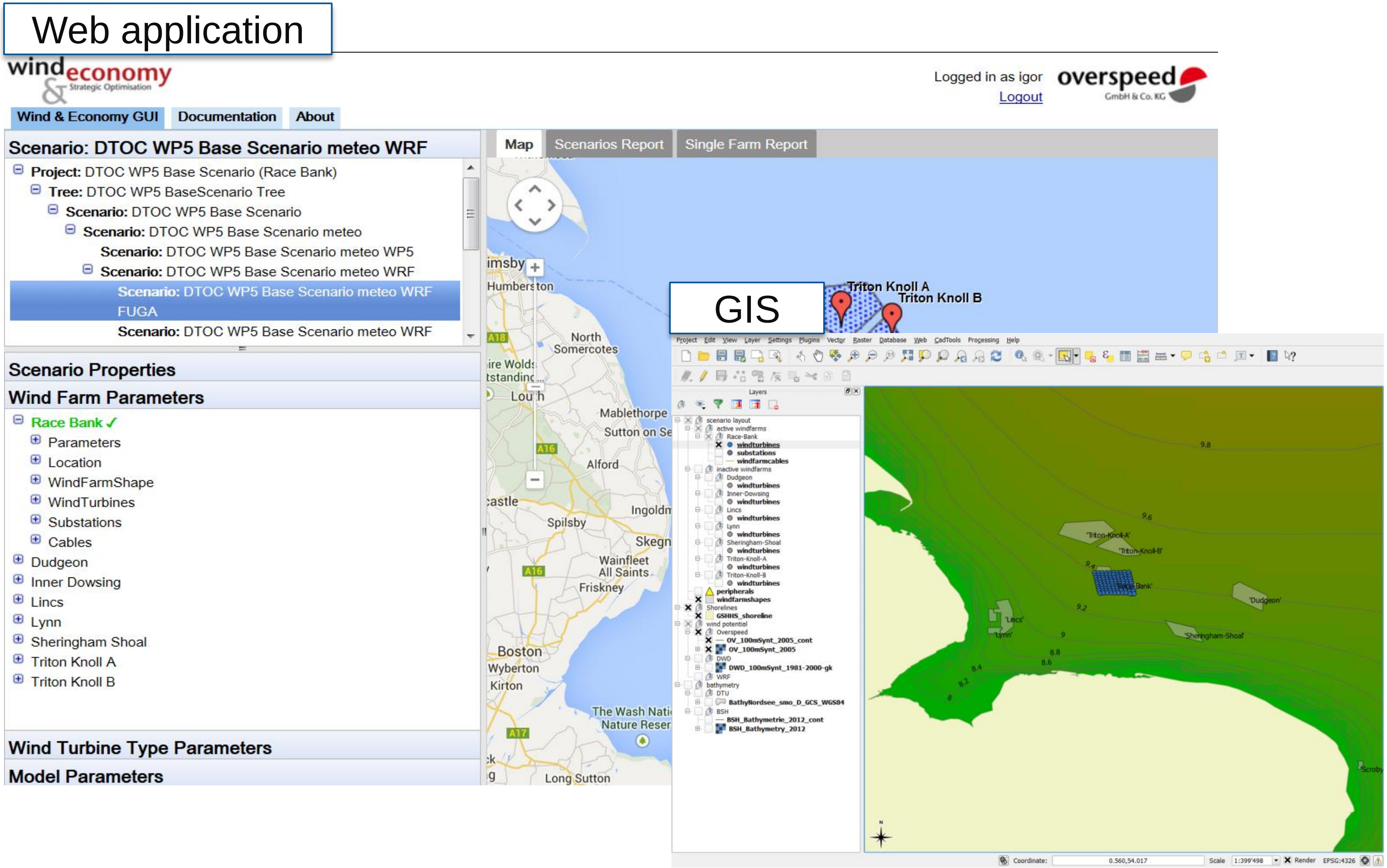




DTOC Design Tool Structure Overview



Local computer: GIS and local web browser



Optimisation process

- As a developer I can **determine the optimum** spacing, position, turbine model and hub height of turbines within an offshore wind farm.

*Software supports the **comparison** of many design scenarios.*

***Comparative** reporting enables selection of optimised configurations.*

Score for comparison: Levelised Cost of Energy

Optimisation Process

1. Generate Design Options

- Scenario 1
- Scenario 2
- Scenario 3
- Scenario 4
- Scenario 5
- Scenario 6
- Scenario 7

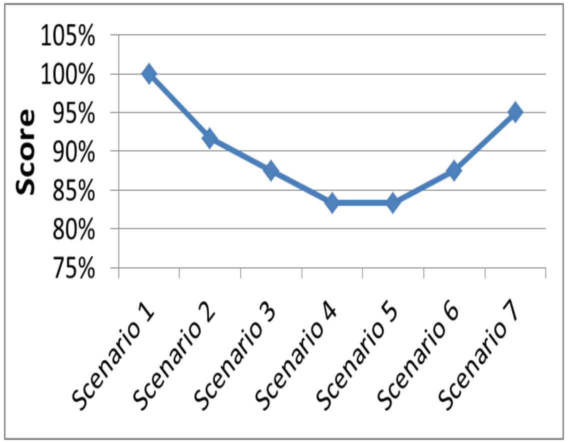
2. Evaluate Design Options

Wake Model

Electrical Model

Energy model

3. Compare Design Options



4. Iterate steps 1 to 3

Score: Levelized cost of energy

What decision parameter can we use to compare design options?

Validation of wake models

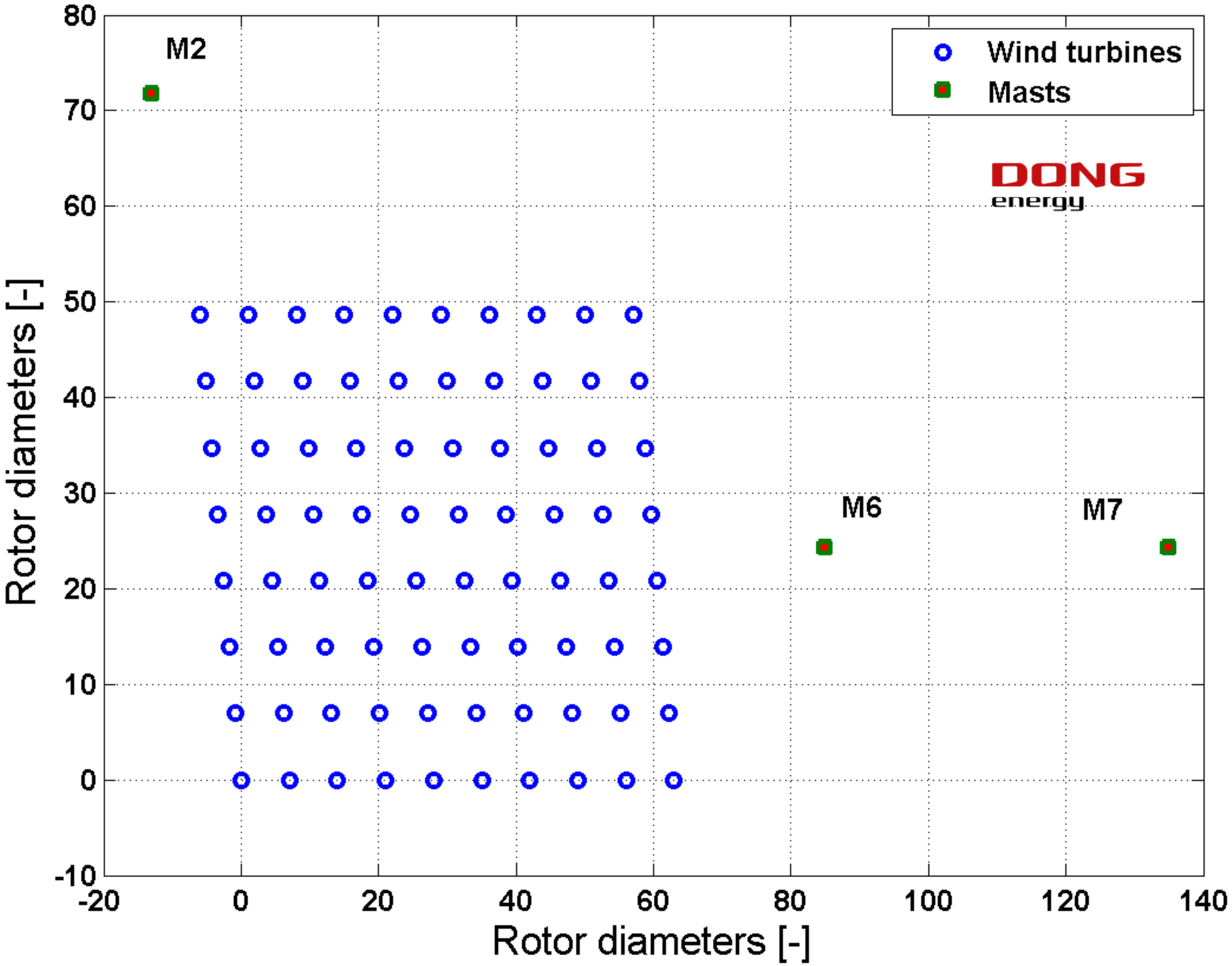
SCADA data at Horns Rev 1, Lillgrund and Rødsand 2 offshore wind farms have been compared to more than 10 wake models

SCADA data and lidar data at Alpha ventus have been compared to three wake models

Satellite data have been compared to four wake models

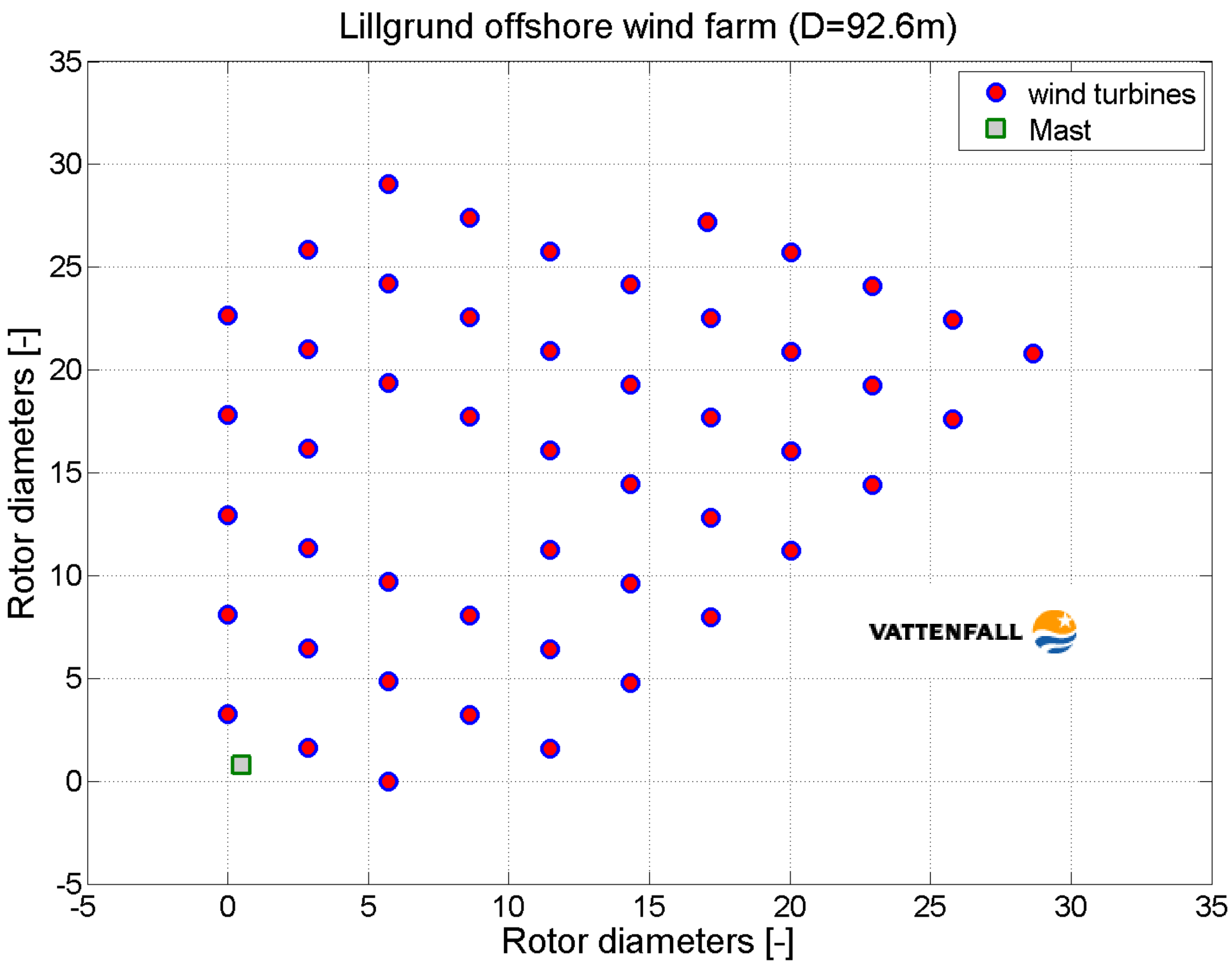
The benchmark concludes that several models were able to handle the clustering of wind farms

Horns Rev 1



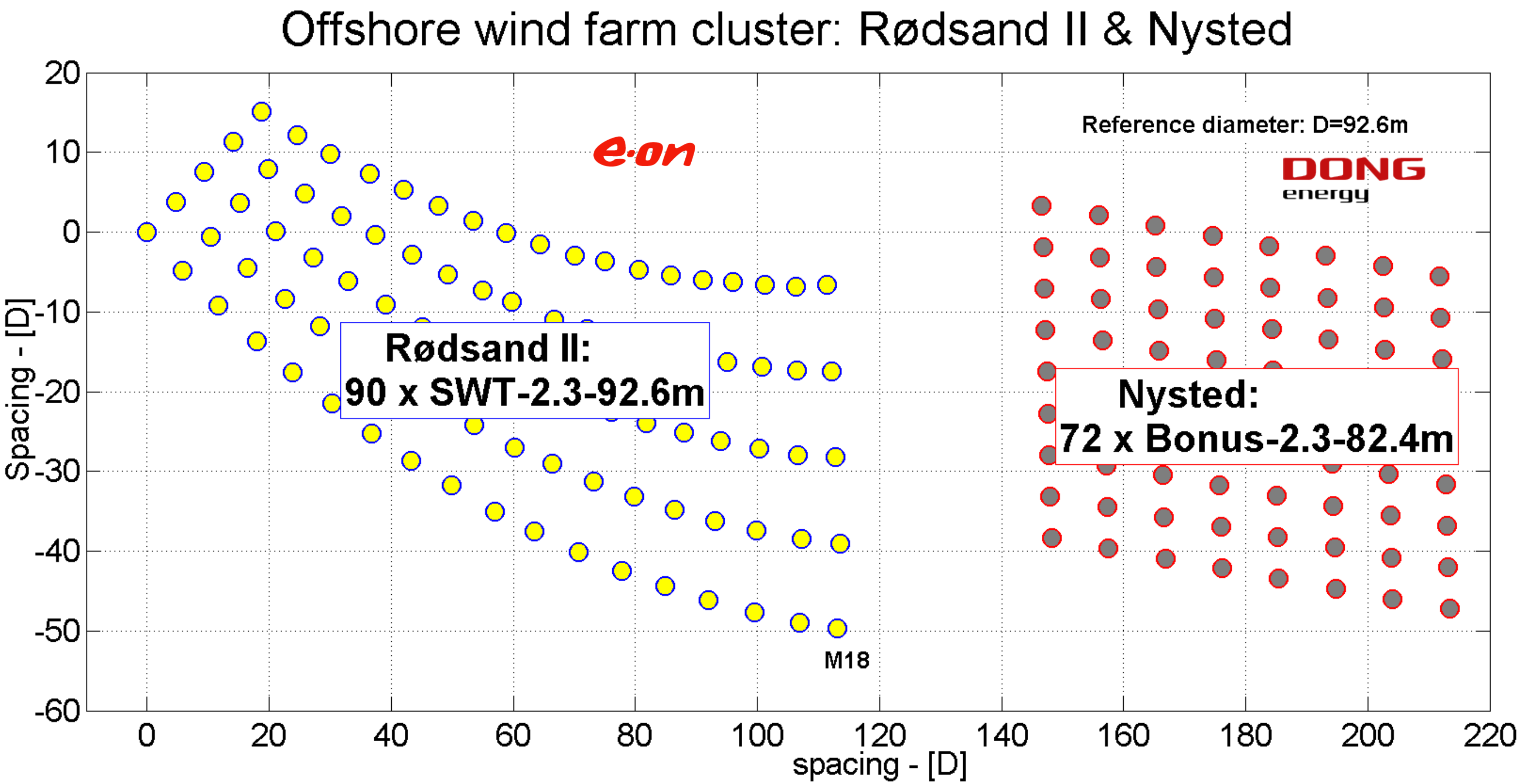
M2
M6
M7
Wind turbines
Masts
DONG energy
80
70
60
50
40
30
20
10
0
-10
-20
0
20
40
60
80
100
120
140
Rotor diameters [-]
Rotor diameters [-]

Lillgrund



Lillgrund offshore wind farm (D=92.6m)
wind turbines
Mast
Rotor diameters [-]
Rotor diameters [-]
35
30
25
20
15
10
5
0
-5
-5
0
5
10
15
20
25
30
35
VATTENFALL

Rødsand-2



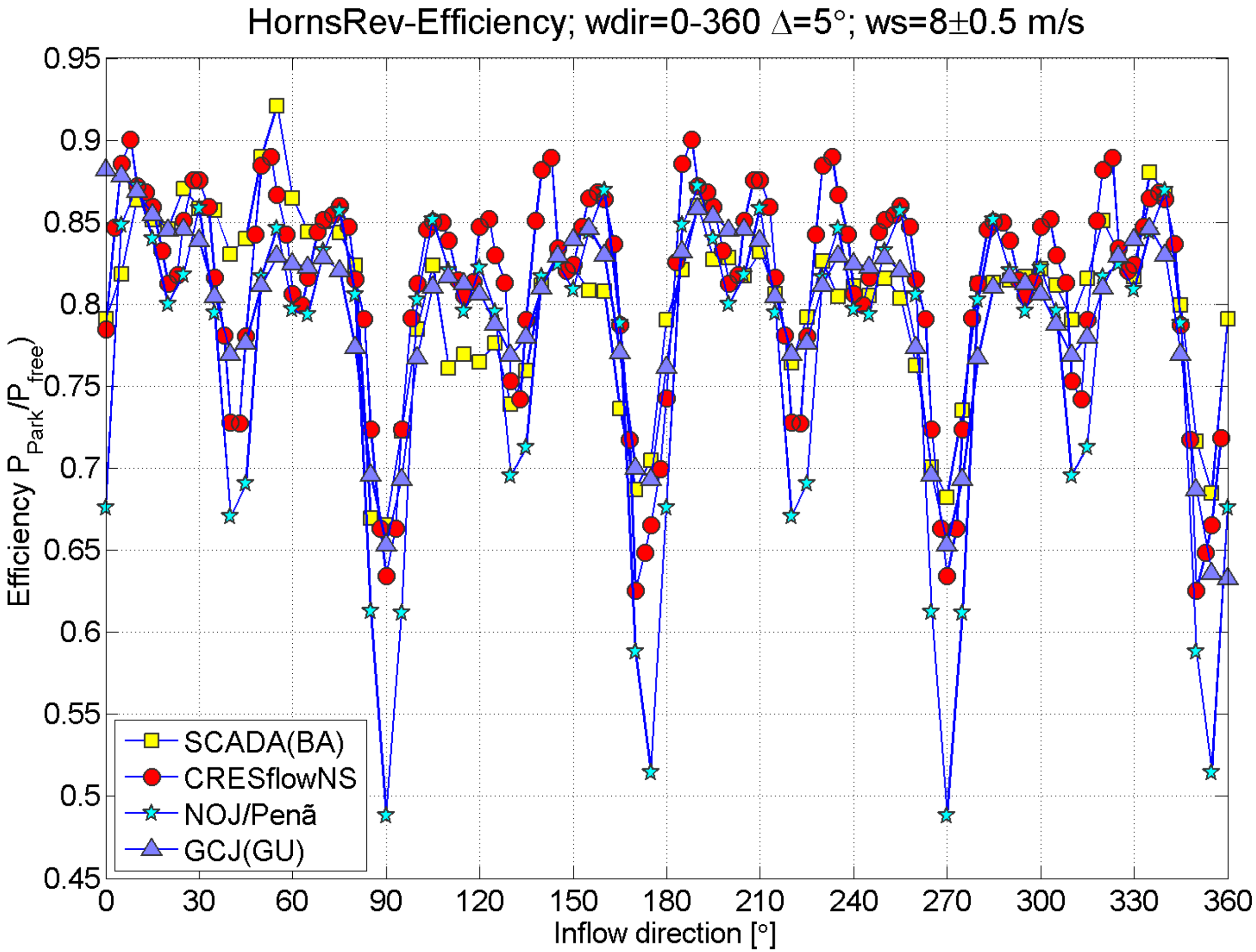
Offshore wind farm cluster: Rødsand II & Nysted
Reference diameter: D=92.6m
e·on
DONG energy
Rødsand II:
90 x SWT-2.3-92.6m
Nysted:
72 x Bonus-2.3-82.4m
M18
Spacing - [D]
spacing - [D]
20
10
0
-10
-20
-30
-40
-50
-60
0
20
40
60
80
100
120
140
160
180
200
220

Participants and park models

Models	Affiliation	Horns Rev WF	Lillgrund WF	Rødsand II WF	Rødsand II/Nysted WF
SCADA/BA	DTU Wind Energy/K.S.Hansen	x	x	x	(x)
NOJ/BA	DTU Wind Energy/misc		x		
NOJ/GU	DTU Wind Energy/misc		x	x	
NOJ/BA	DTU Wind Energy/A. Pena	x	x	x	
WASP/NOJ	Indiana Uni/RB	x			
GCL/BA	DTU Wind Energy/misc		x		
GCL/GU	DTU Wind Energy/misc	x	x		
GCL(GU)	CENER/JS.Rodrigo	x	x		
FUGA/SO	DTU Wind Energy/S. Ott	x	x	x	
DMW	DTU Wind Energy/TJ.Larsen	x			
AD/RANS	UPORTO/J.L. Palma	x		x	x
CRESflowNS	CRES/ J. Prospathopoulos	x	x	x	
FarmFlow	ECN Wind Energy/J.G Scheepers	x	x	x	x
CFDWake	CENER/B.G. Hevia	x		x	
RANS/f_PC	DTU Wind Energy/P.vd Laan			x	x
Ainslie	RES-LTD/T.Young	x	x		
WRF/UPM	Ciemat/A.Palomares			x	
Mesoscale	DTU Wind Energy/P.Volker			x	

BA=Bin averaged & GU=Gaussian Uncertainty

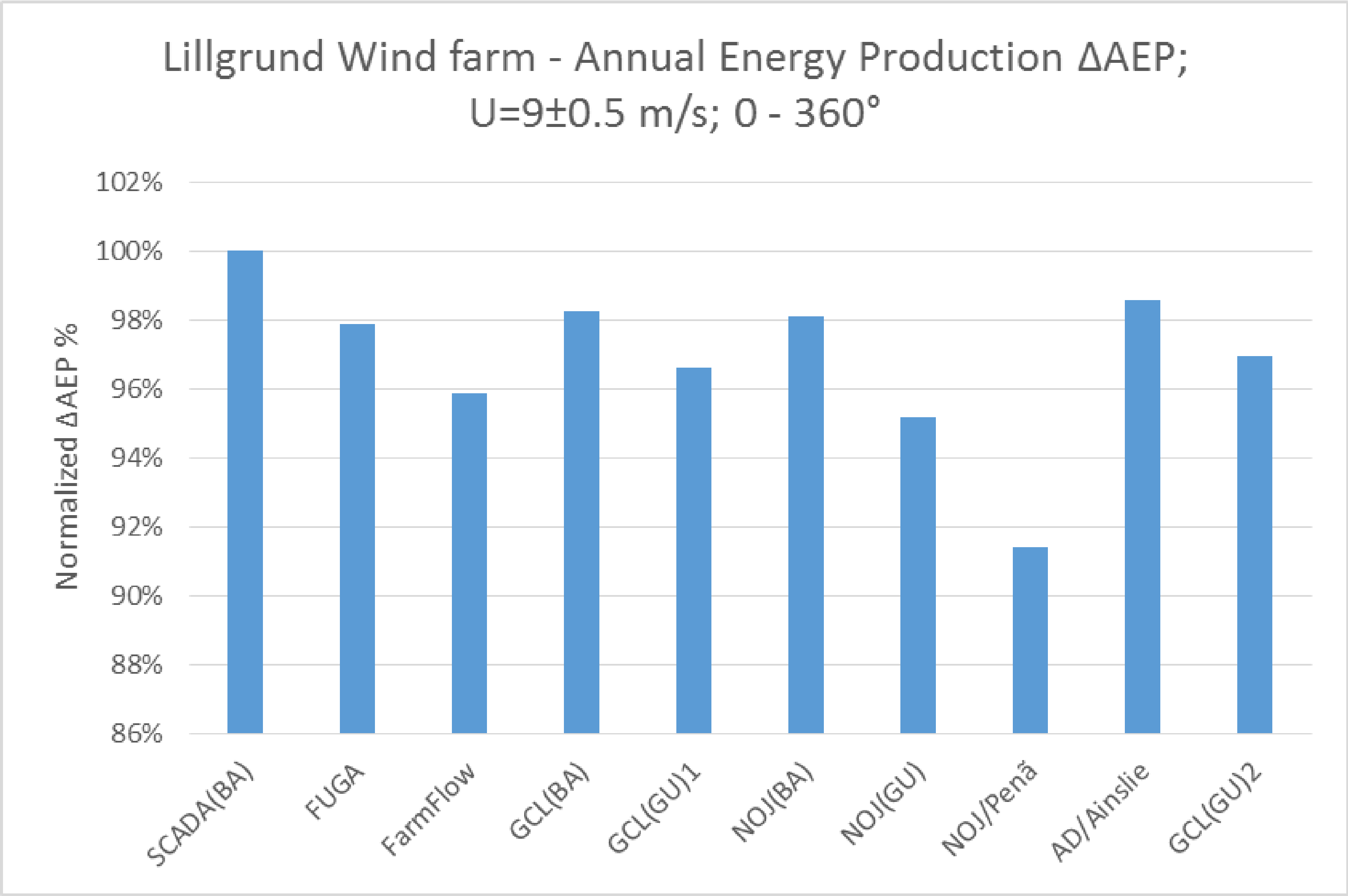
Horns Rev park efficiency @ 0 - 360°



Horns Rev benchmark - conclusion

- First EERA-DTOC benchmark included 11 models, which have been implemented succesfull;
- The basic flow cases displayed some sector size dependent differences;
- The park efficiency case demonstrated that the participating models are able to handle a complete wind farm consisting of 80 turbines.

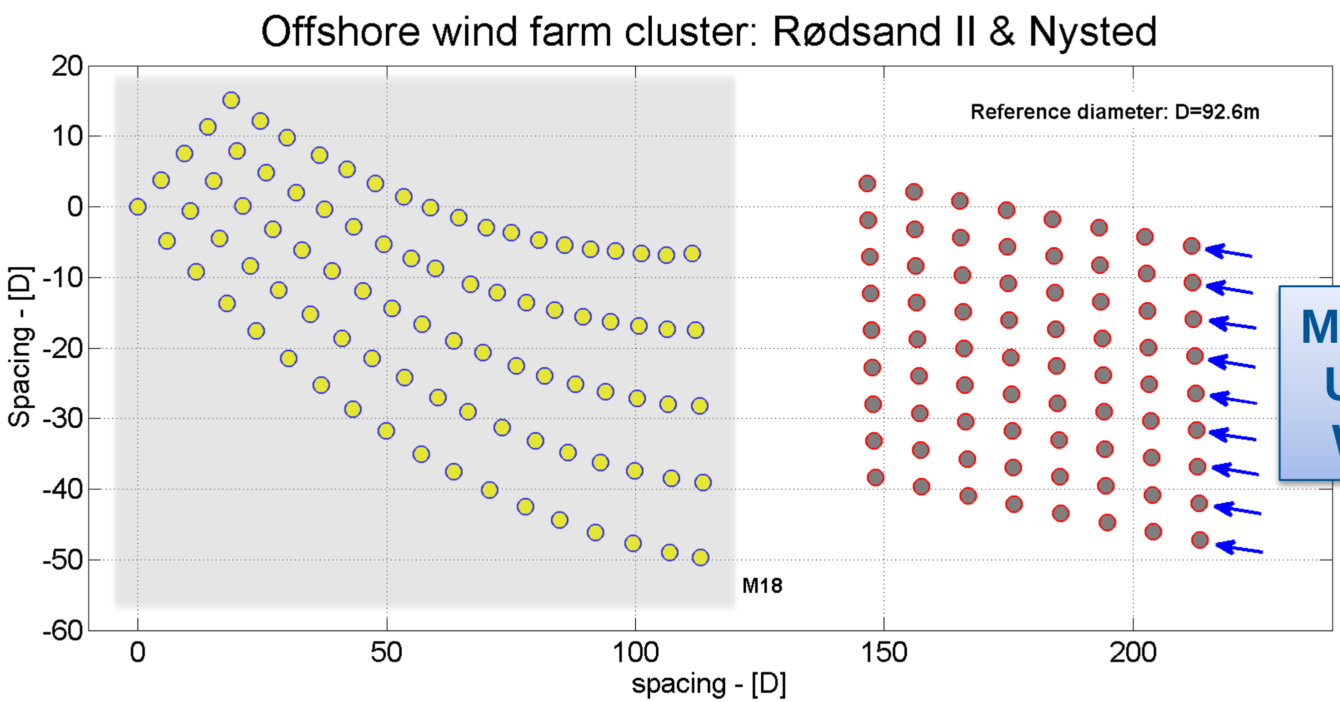
Lillgrund park efficiency @ 0 - 360°



Lillgrund benchmark - conclusion

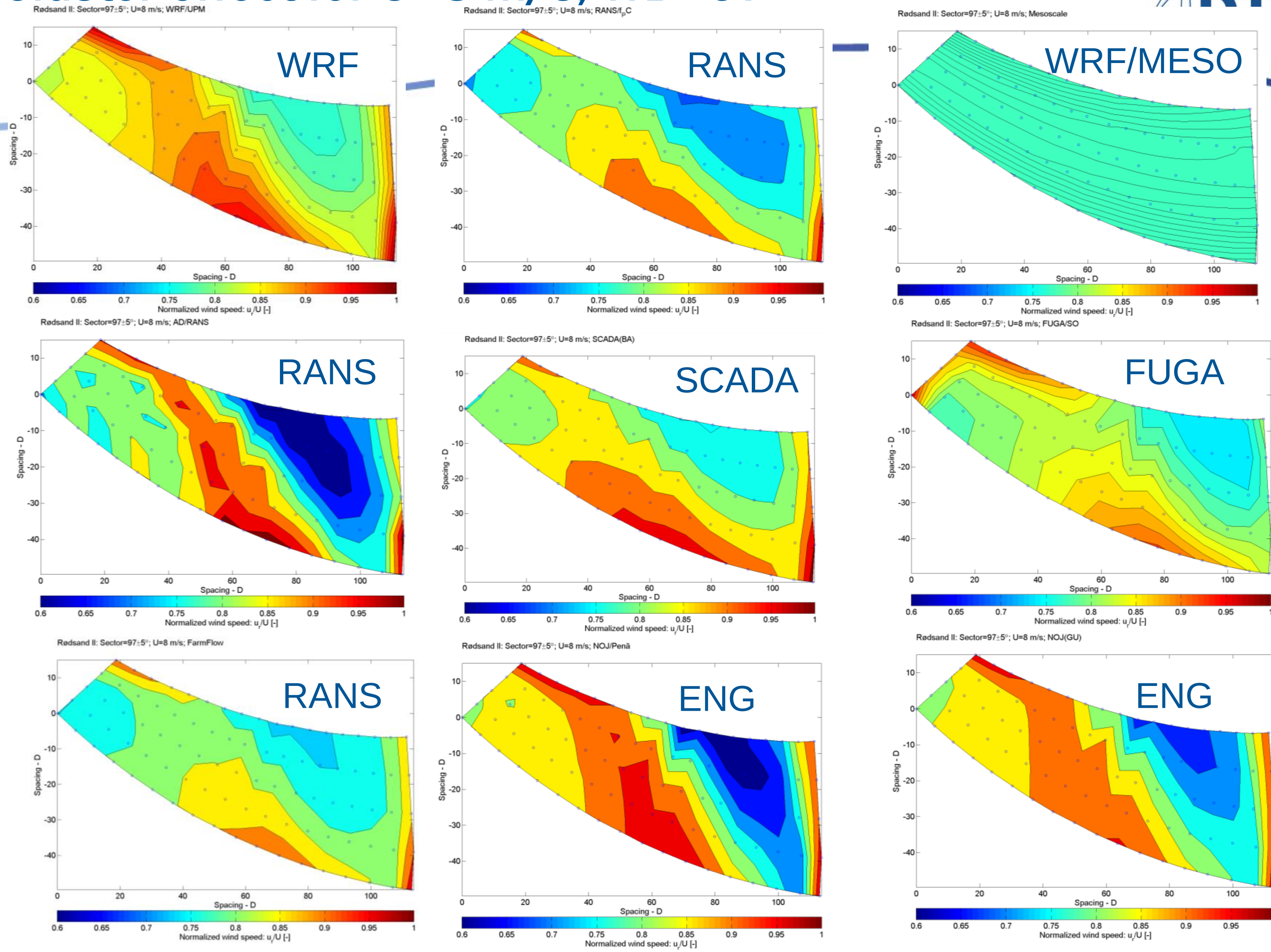
- All models handles 3.3 and 4.3D spacing well;
- All models handles the speed recovery due to ”missing” turbines;
- All models were able to simulate the park efficiency for 0 - 360° inflow;
- The simulated ΔAEP demonstrates a variation of ±3% compared to the measured value;

Rødsand-2 wind farm cluster effect

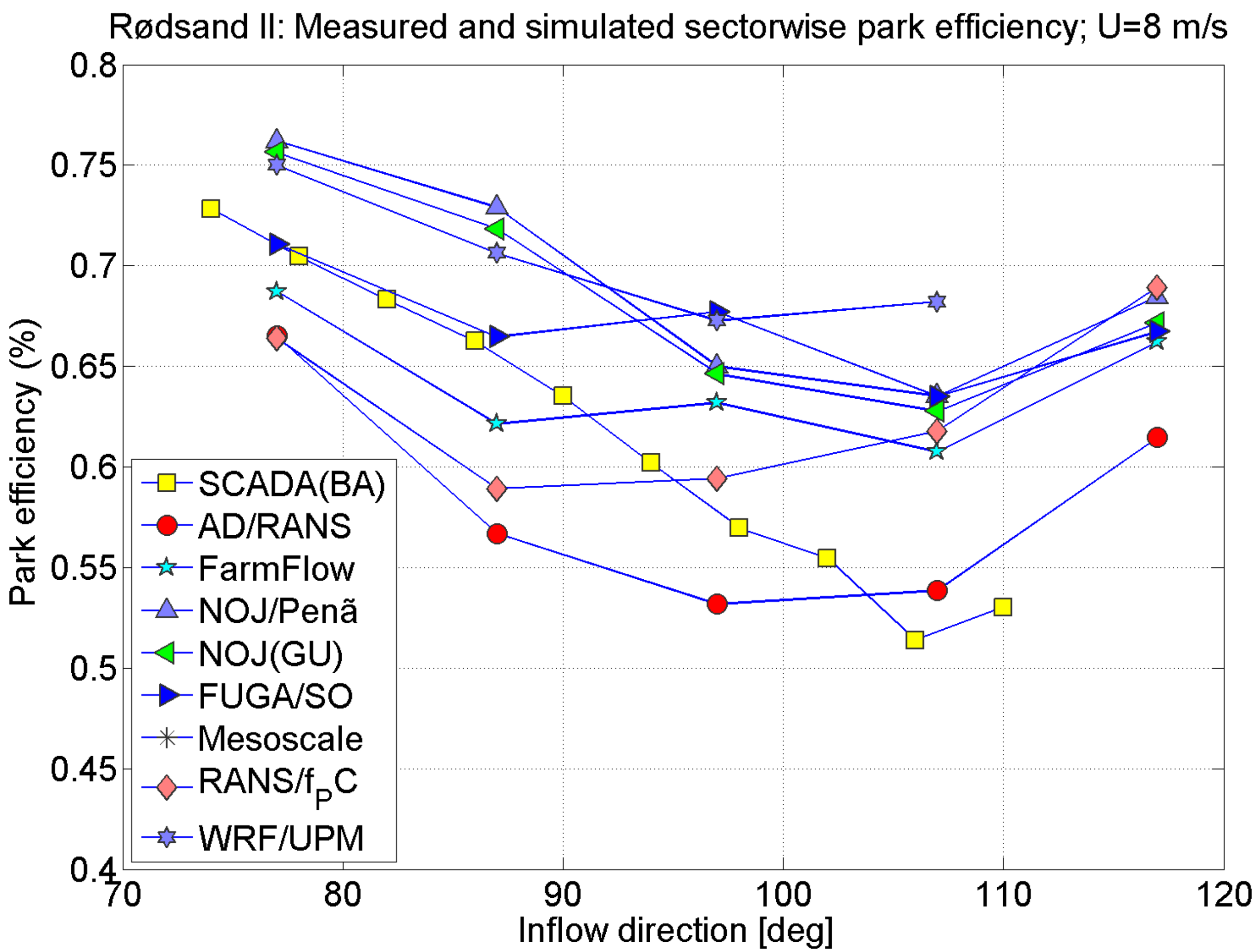


Model inflow
U_{hub}=8 m/s
WDIR=97°

Cluster effect for U=8 m/s; WD=97 °



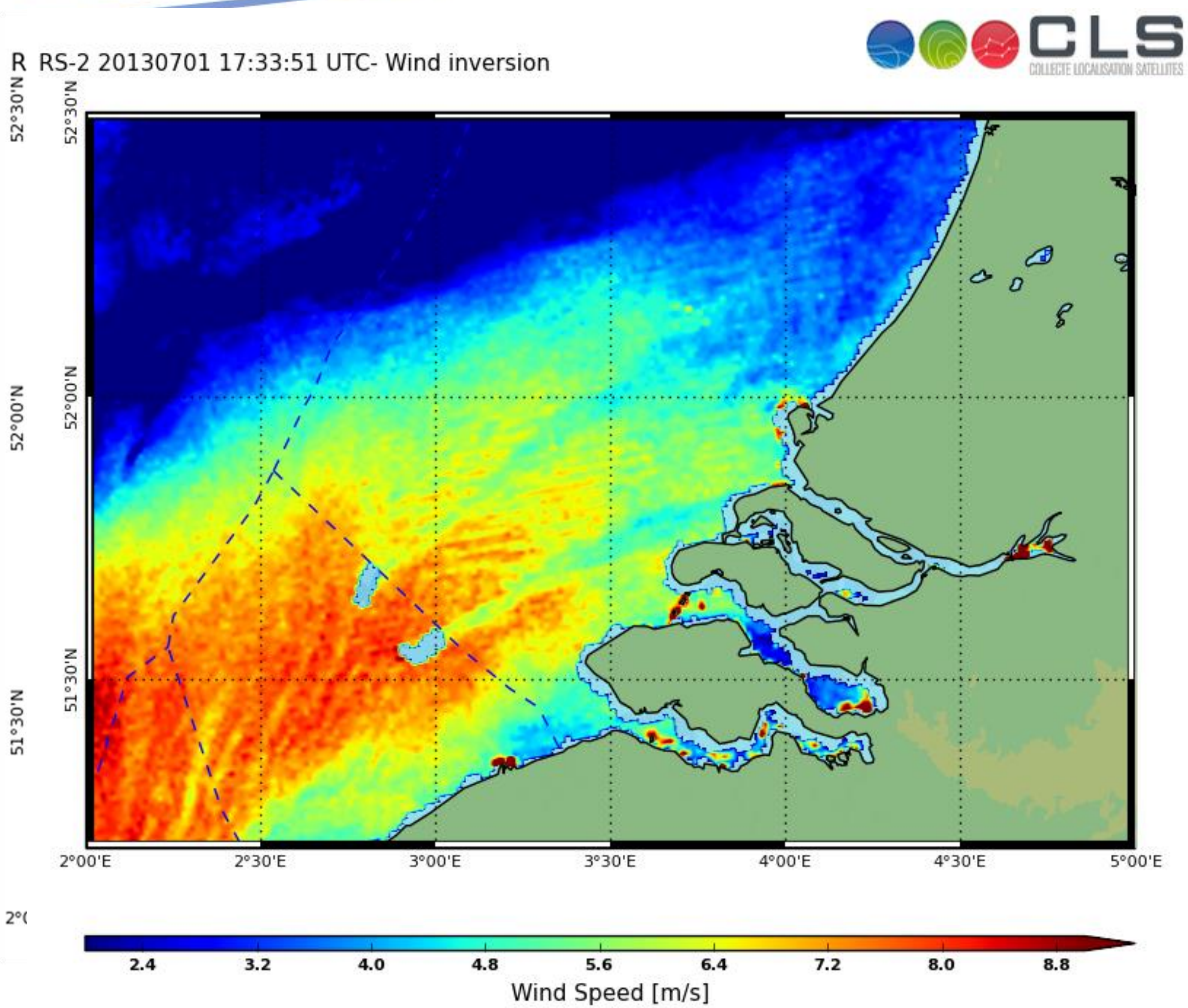
Rødsand-2 park efficiency @ 77-118°



Rødsand cluster effect - conclusion

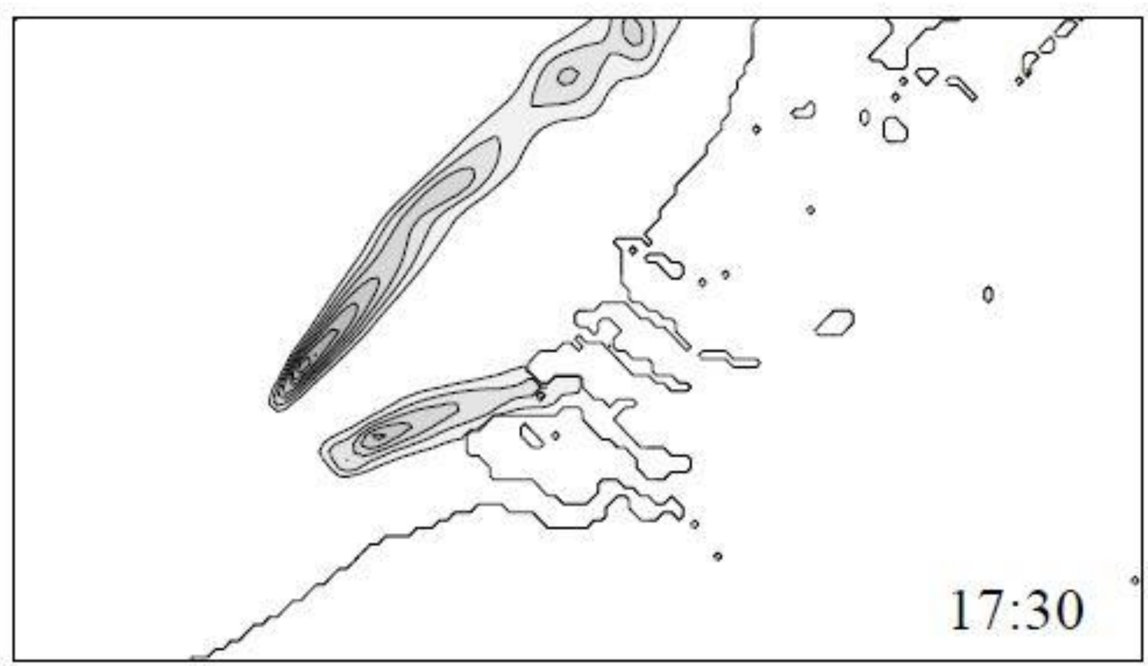
- Quantification of the cluster effect is not possible due to lack of measurements and park asymmetries.
- The benchmark has demonstrated that both size and location of the distinct deficit zone - caused by the Nysted wind farm has been predicted quite well by the models.
- The benchmark concludes that several models were able to handle the clustering of wind farms.

Satellite



Pauline Vincent

WRF



Velocity deficit with contours in ranges from -1.25 to -0.1 ms^{-1} over the sea surface only

Patrick Volker

WRF V3.4
ERA Interrim
Nests 18 km, 6 km, 2 km
12 m amsl
MYNN
EWP scheme applies a grid-cell averaged deceleration to the model's flow equation and additional turbulence is produced by the PBL scheme from the changed vertical shear in horizontal velocity.

Volker, P.J.H., Badger, J., Hahmann, A.N., Ott, S. *Geosci. Model Dev. Discuss*., 8, 3481–3522, 2015

Further reading

Energies **2015**, *8*, 5413-5439; doi:10.3390/en8065413

OPEN ACCESS

energies

ISSN 1996-1073

www.mdpi.com/journal/energies

Article

Using Satellite SAR to Characterize the Wind Flow around Offshore Wind Farms

Charlotte Bay Hasager [1,*], Pauline Vincent [2,†], Jake Badger [1,†], Merete Badger [1,†], Alessandro Di Bella [1,†], Alfredo Peña [1,†], Romain Husson [2,†] and Patrick J. H. Volker [1,†]

[1] Technical University of Denmark, Wind Energy Department, Frederiksborgvej 399, Roskilde 4000, Denmark; E-Mails: jaba@dtu.dk (J.B.); mebc@dtu.dk (M.B.); adia@dtu.dk (A.D.B.); aldi@dtu.dk (A.P.); pvol@dtu.dk (P.J.H.V.)

[2] Collecte Localisation Satellites, Avenue La Pérouse, Bâtiment le Ponant, Plouzané 29280, France; E-Mails: pvincent@cls.fr (P.V.); romain.husson@cls.fr (R.H.)

Wind & economy

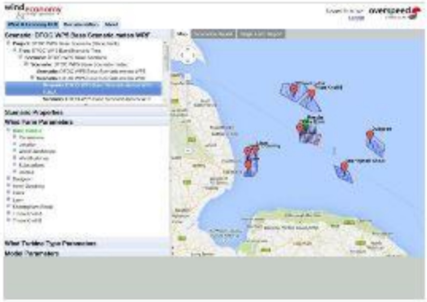
SUBSCRIBE NEWSLETTER | LEGAL NOTICE | SITEMAP

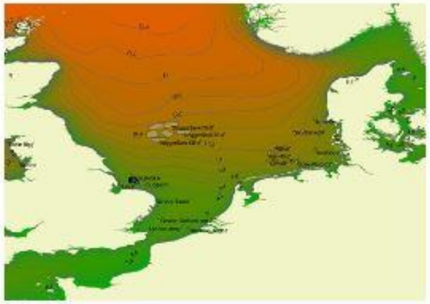
wind & economy Strategic Optimisation

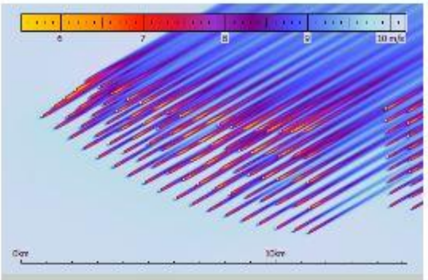
- Home
- News
- Strategic Optimisation Software
  - Wind Farm Optimisation
  - Wind Farm Scenarios
  - Wind Resource
  - Wake Losses
  - GIS Integration
  - Uncertainty Modelling for Risk Management

Welcome to Wind & Economy

One of the most challenging tasks for wind farm developers is the optimisation of offshore wind power plants. Our new software tool, Wind & Economy, supports your challenging work with the seamlessly integrated modelling of wind climate, large scale and localized wind farm effects, electrical loss calculations and derivation of economic key figures.







http://wind-and-economy.com/home/

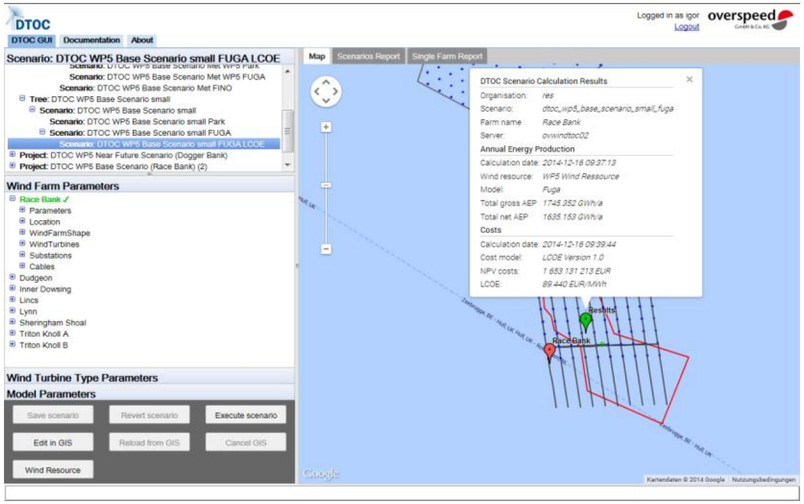
Wind & Economoy:
The tool for wind farm optimization

- wind climate
- turbine type selection
- turbine spacing and placing

- interaction between wind farms in clusters with respect to energy production

- LCOE and economic uncertainty

- Scenario approach
- GIS integration



Bringing leading edge modelling to your desktop

Conclusion

The main project output, the ‘Wind & Economy’ software, provides a new frame for planning offshore wind farm clusters.

By seamless integration of state- of-the-art models from the scientific development by the EERA members, which have been compared and validated by the research community and end-users, provides a significant potential for cost reductions.

The rapid development of offshore wind farms in the Northern European Seas with major clusters planned in many countries makes the release of this novel tool available with due diligence.

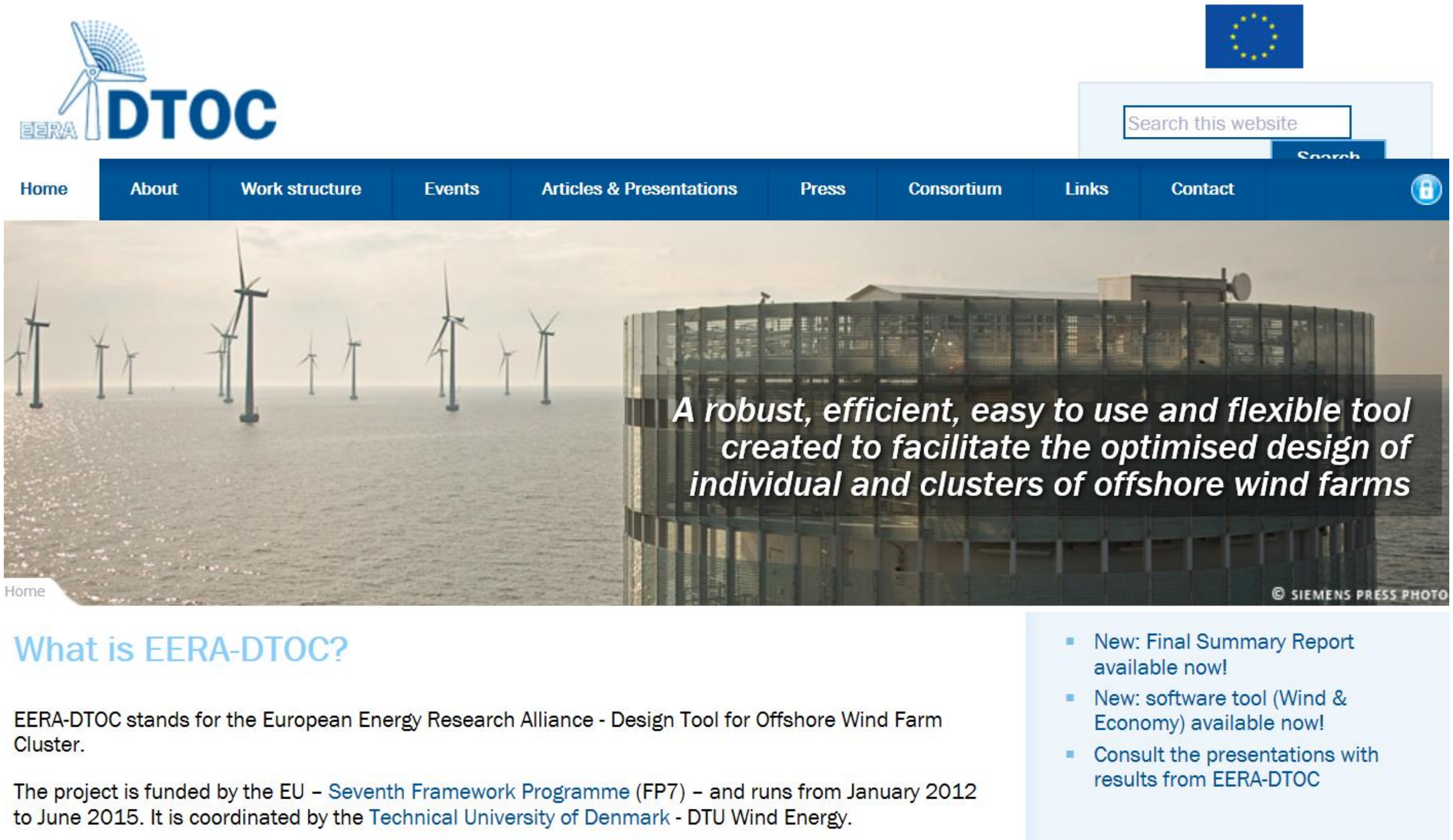
Future

We aim at developing the tool for strategic planners

1) Add environmental aspects and restricted zones
2) Add sea bed and estimate foundation costs
3) Improved cost of energy and O&M module
4) Further detail wind farm cluster effects
5) Include social acceptance

DTU has submitted EUDP2015 proposal (Danish national activity).

Visit www.eera-dtoc.eu



Support by

This project has received funding from the European Union’s Seventh Programme for research, technological development and demonstration under grant agreement No FP7-ENERGY-2011-1/ n° 282797

Acknowledgements:
Funding: EERA DTOC FP7 and partners
SCADA data: DONG energy, Vattenfall, E.On, RAVE
Radarsat image: MacDonald, Dettwiler and Associates Ltd.
Wake modelling more than 20 participants at many partner institutes